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EFFECT OF THE MANUFACTURING PARAMETERS OF FLOAT-GLASS ON ITS HEAT-TOLERANCE

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The results of investigations of the heat-tolerance of 4.0 – 12.0 mm thick heat-absorbing float-glass are presented. It is shown that the heat-absorbing glass possesses high heat-tolerance (> 100°C). It is concluded on the basis of the character of the heat-tolerance over the width of the ribbon that the heat-tolerance of float-glass depends on manufacturing processes such as formation and annealing.

Key words: heat-tolerance of glass, float-ribbon, heat-absorbing glass, production technology.

Glass with high strength is finding increasingly wider applications in construction, in automobile manufacturing, as well as in the manufacture of aviation glass articles with larger size, fewer laminations, and higher weight and optical indices [1].

One strength characteristic of glass is its heat-tolerance, i.e., the capability to withstand sharp temperature differentials without breaking. Publications present largely the results of investigations of the heat-tolerance of glass rods, glass filters, and glasses in simple systems of the type “metaphosphate-phosphorus anhydride” which are synthesized under laboratory conditions [2, 3].

The investigations of heat-tolerance of industrial sheet glass obtained by vertical drawing [4, 5] have shown that the heat-tolerance of the glass depends on its chemical composition, thickness, shape, linear dimensions, as well as the mechanical strength, intensity of the heat action, and other factors.

The objective of the present work is to determine the manufacturing factors that affect the heat-tolerance of float-glass.

We have investigated the heat-tolerance of heat-absorbing glass, obtained on pilot float-line at the Saratov Institute of Glass.

The heat-tolerance was investigated by a method developed on the basis of GOST 11103–85 [6].

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In practice, glass articles are often exposed to water or air. The most stringent conditions are in the tests performed on glass in water, so that the results of such tests are more indicative and form basis for the method used to determine the heat-tolerance of the glass.

The essence of the method used to measure the heat-tolerance consists in determining the stability of the heated samples of glass with respect to a sharp change of the temperature when they are cooled in water.

The difference of the glass and water temperatures at which a sample fractures is a measure of the heat-tolerance:

$$Q = T_2 - T_1,$$

where Q is the heat-tolerance, °C; T_2 is the temperature of the heated glass, °C; and, T_1 is the temperature of the water, °C.

The following equipment was used in our investigations: an electric muffle furnace, holding frames for glass of different thickness, and a container with cooling water. The tests were performed on 100×100 mm samples cut in a strictly determined order over the entire width of the glass ribbon. To eliminate the effect of factors which are unrelated to the manufacturing technology (mechanical damage, scratches, and others) the samples were taken directly from the float-line. In the process, the manufacturing parameters of the glass production (chemical composition and thickness of the glass, rate of production of the ribbon, and others) and defects which appear when the glass is cut out (nicks, breaks, marks form a roller) were recorded.

To determine the heat-tolerance the glass samples inserted in the holding frame were placed in an electric furnace

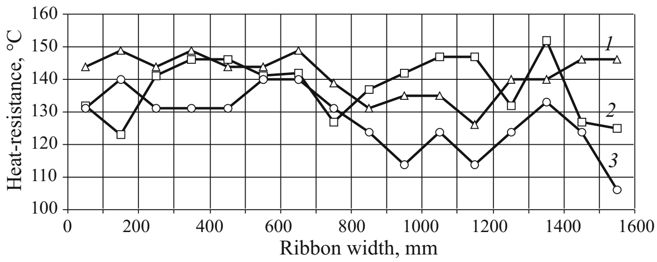

Fig. 1. Distribution of the heat-tolerance of bronze glass with different thickness over the width of the glass ribbon: *1*, *2*, *3*) thickness 4, 6, and 8 mm, respectively.

and heated for a definite period of time sufficient for to them to be heated uniformly over the thickness (at least 5 min per 1 mm of glass thickness). Next the samples were successively immersed into the water tank (temperature 17 – 25°C). The tests were performed by increasing the temperature in steps until all samples fractured. It should be noted that when determining the heat-tolerance of the glass the furnace temperature was increased in 5°C steps, and the water temperature was checked before each immersion of the samples. This reduced the possible measurement error (obtaining too high a value for the heat-tolerance), which the authors of [2] cite, to a minimum.

The heat-tolerance of the samples of sheet glass depends on the quality of their edges, since a narrow defective track in the form of breaks and skin cracks, which are stress concentrators in the glass, inevitably remains in the surface of the glass sample when a cutting roller is used for the cutting. After breaking, these stresses form on the glass surface (along its edge) a weakened zone whose size can reach 0.6 mm (according to data obtained at Scientific–Research Institute of Technical Glass, JSC). In addition, the edges of the glass samples are cooled more sharply when the glass is immersed vertically into the water. For this reason, when the heat-tolerance of glass samples is determined the edges of the glass must be covered (heat-insulated) [4].

The tests showed that the heat-tolerance of the samples of heat-absorbing float-glass with uncovered edges is about 27% lower than for covered edges. Glass edges can be heat-insulated using various materials, for example, asbestos, aluminum foil, and white plaster. We chose as the heat-insulating materials transparent self-bonding film, which makes it possible to observe the character of the damage to the edge and the ends of the glass and to obtain a video of the glass samples as they undergo the tests. In addition, this film withstands high temperatures (up to 170°C) without damage; this is sufficient to perform measurements of the heat-tolerance of sheet glass. The glass edges were protected in a manner so that the ends, edges, and edge zones of the surfaces (at least 6.0 mm wide) are covered.

In the course of our studies we performed measurements of the heat-tolerance of heat-absorbing (bronze and gray) glass with thickness 4.0 – 12.0 mm, produced with different rates of production of the glassmaking furnace. Sixteen samples (with glass ribbon width 1600 mm) were taken for each type of test and the average value of their heat-tolerance was calculated.

TABLE 1. Heat-Tolerance of Different Types of Heat-Absorbing Float-Glass

Glass type	Glass thickness, mm	Average heat-tolerance, °C	Heat-tolerance differential over glass-ribbon width, °C
Bronze	4.0	141	23
	5.0	140	24
	6.0	138	29
	8.0	127	34
	10.0	118	33
	12.0	110	34
Grey	5.0	135	42
	10.0	114	36
	12.0	96	43
	13.0	94	31

The results of the tests showed that in all cases the heat-tolerance distribution over the width of the glass ribbon is nonuniform (Fig. 1).

The heat-tolerance distribution of the glass over the ribbon width (with characteristic dips in definite locations) is similar to the distribution of the residual stresses, optical distortions, and surface strength of the glass on a centro-symmetric bend. Therefore, it can be concluded that the heat-tolerance of float-glass depends on the glass formation and annealing processes.

Figure 1 shows that there exists a substantial differential of the heat-tolerance over the width of the glass ribbon. The maximum heat-tolerance differential over the ribbon width reaches 34°C for bronze glass and 43°C for grey glass (the data are presented in Table 1).

It follows from the data in Table 1 that the heat-tolerance of grey glass is lower than that of bronze glass, especially for glasses of thick ratings.

The results of the tests made it possible to determine the dependence of the heat-tolerance of glass on its thickness (Fig. 2). The investigations showed that the heat-tolerance of bronze and grey glasses decreases as thickness increases (the heat-tolerance of 5.0 mm thick glass is about 1.4 times higher than that of 12.0 mm thick glass). This dependence is probably due to the lower strength index of thick glasses as compared with thin glasses and with increasing temperature gradient over the glass thickness when the glass is sharply cooled [4].

To compare the heat-tolerance of colorless and heat-absorbing glasses additional tests of the heat-tolerance of colorless float glass 6.0 m thick were performed. As Fig. 3 shows, the heat-tolerance of colorless glass is somewhat higher than (by about 6%) that of bronze glass.

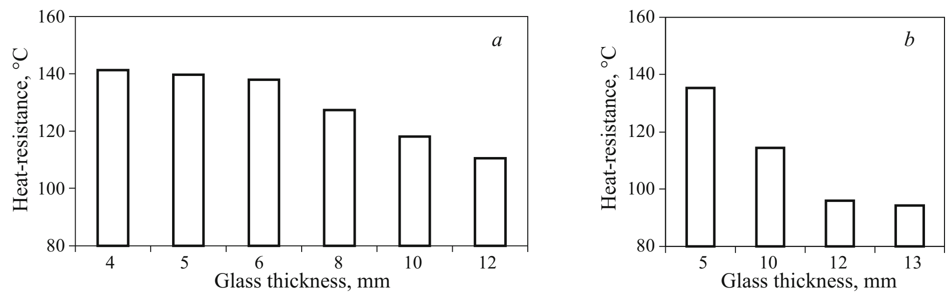

Fig. 2. Heat-tolerance of heat-absorbing glass versus its thickness: *a*) bronze-colored glass; *b*) grey-colored glass.

The dependence of the heat-tolerance of different forms of float-glass on the form and concentration of metal additives in the batch can be explained by the fact that in the production of colorless glass the thickness of active layer, going to production, is larger than in heat-absorbing glass. On the other hand, this is explained by changes in the structure of the glass (embedding of Me ions in the structure of the glass network with formation of the chains $\equiv Si - O - Me - O - Si \equiv$), which is confirmed by the spectral analysis of colorless and heat-absorbing glasses.

In addition, the dependences of the heat-tolerance of bronze glass on the production rate of a glassmaking furnace were investigated. The measurements were performed on glass produced on a single float-line with different production rates of the furnace (120, 135, 150 tons/day) (Fig. 4). As Fig. 4 shows, the heat-tolerance of 4.0 mm thick glass remains virtually unchanged as the furnace production rate increases from 120 to 150 tons/day.

In summary, it has been found that heat-absorbing float-glass possesses high heat-tolerance and is capable of withstanding a temperature differential higher than 100°C. The heat-tolerance of the glass depends on the type and concentration of coloring additives in the batch and is practically independent of the production rate of the glassmaking furnace. The existing differential of heat-tolerance over the width of a glass ribbon attests to the dependence of the heat-resistance of float-glass on technological processes such as formation and annealing.

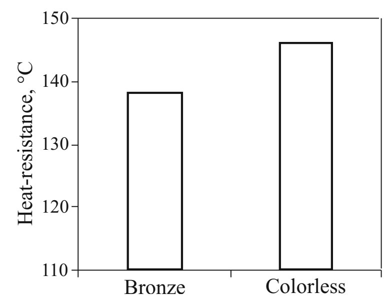

Fig. 3. Heat-tolerance versus glass type.

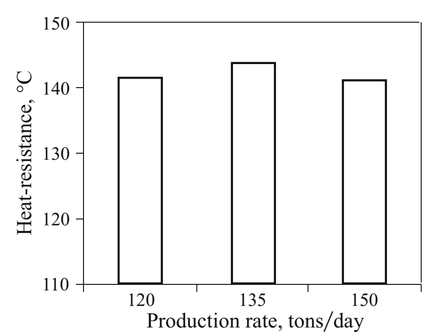

Fig. 4. Heat-tolerance versus production rate of a glassmaking furnace.

REFERENCES

1. V. F. Solinov, "Scientific–Research Institute for Technical Glass, JSC," *Steklo Keram.*, No. 9, 5 – 6 (2000).
2. A. M. Butaev, I. N. Vygorka, L. G. Perevozchikova, and A. N. Yaborov, "Use of ion-exchange method to increase the heat-tolerance of glass filters," *Steklo Keram.*, No. 10, 10 – 12 (1984); A. M. Butaev, I. N. Vygorka, L. G. Perevozchikova, and A. N. Yaborov, "Use of ion-exchange method to increase the heat-tolerance of glass filters," *Glass Ceram.*, **41**(10), 434 – 438 (1984).
3. O. S. Shchavelev, V. A. Babkina, N. K. Mokin, and N. A. Ivanova, "Heat-tolerance of binary meta-ultraphosphate glasses," *Fiz. Khim. Stekla*, **14**(1), 61 – 65 (1988).
4. G. M. Bartenev, *Mechanical Properties of and Heat Treatment of Glass* [in Russian], Moscow (1960), pp. 149 – 164.
5. V. F. Solinov, T. V. Kapkina, and A. V. Gorokhovskii, "Effect of the formation parameters on the thermomechanical properties of silicate sheet glass," *Steklo Keram.*, No. 5, 7 – 8 (1992); V. F. Solinov, T. V. Kapkina, and A. V. Gorokhovskii, "Relationship between the thermomechanical properties and shaping parameters of silicate sheet glass," *Glass Ceram.*, **49**(5), 7 – 8 (1992).
6. *GOST 11103–85, Inorganic Glass and Glass-Crystalline Materials. Method of Determining Heat Tolerance* [in Russian], Moscow (1985).